Creating Our Tomorrows
LDRD Day 2012

Laboratory Directed Research and Development
Los Alamos National Laboratory
October 23, 2012

Energy Security and Technology Surprise

Stockpile Stewardship

Defense Against Nuclear Threats

Scientific Discovery

Innovation for Our Nation

Laboratory Directed Research and Development
Los Alamos National Laboratory
505-667-1230 (phone)
ldrd@lanl.gov (email)

Visit us online at http://tri-lab.lanl.gov/

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Welcome to LDRD Day 2012

America faces energy, security, economic, and environmental challenges that, in their scope and complexity, are perhaps unparalleled in the nation's history. Los Alamos National Laboratory is called upon to respond to those challenges; as a premier national security science laboratory, our Federal sponsors (and others) count on us to address these challenges by technical means.

Congress has authorized the national laboratories to invest in technical capabilities and new mission solutions through the Laboratory Directed Research and Development (LDRD) program. LDRD supports the most advanced, high-risk ideas at Los Alamos. Many of the Laboratory's successes, which range from the heavens (the Earth's radiation belts and their effects on satellites) to the Earth (the accelerated cleanup of the Rocky Flats site near Denver), can be traced to LDRD.

LDRD investments are rigorously selected, based on the independent judgments of leading scientists and engineers, inside and outside the Laboratory. LDRD is a small fraction of the Laboratory budget, capped at 8 percent for National Nuclear Security Administration laboratories. In a nutshell, LDRD is how the Laboratory steps into action to build the future of its science and technology.

That future revolves around the national challenges in energy security, nuclear security, and global security, and is driven forward by the engine of scientific discovery. At LDRD Day, we showcase the ideas being pursued by some of the leading scientists and engineers of the Laboratory. What you will see is a small sample of the excitement of LDRD, but enough to give a feel of the breadth and quality of the work. This select research is one of the best ways to understand the future of what Los Alamos will deliver to the nation.

Dr. William Priedhorsky
LDRD Program Director
Los Alamos National Laboratory

William Priedhorsky received a bachelor's degree in physics *summa cum laude* and Phi Beta Kappa from Whitman College in 1973, and a Ph.D. in physics, specializing in x-ray astronomy, from the California Institute of Technology in 1978. Since joining Los Alamos National Laboratory as a staff member in 1978, his research has spanned the gamut from development of time-resolved, spectral, and imaging x-ray instrumentation, to new technologies to stymie the spread of weapons of mass destruction. He has earned numerous awards for distinguished performance in his career, most recently an honorary degree of humane letters from Whitman College.

Invited Speakers

Steven Beckwith

Steven Beckwith is the Vice President for Research and Graduate Studies at the University of California in the Office of the President, responsible for promoting the five billion dollar annual research enterprise across the ten campus system and assisting with their mission to train young scholars. He is also a Professor of Astronomy at the University of California Berkeley, where he teaches and carries out research. His 30-year research career spans a wide spectrum of interests including the formation and early evolution of extra-solar planetary systems, the birth of new stars, and the birth of galaxies in the early universe. He has published his research widely, won several awards for his work, and speaks to public and professional audiences about the importance of research.

He was educated at Cornell University, receiving a bachelor's degree in Engineering Physics in 1973, and at Caltech, receiving a doctorate in physics in 1978.

In 2004, he led the team that created the Hubble Ultra Deep Field, the deepest visual image of the universe, resulting in the discovery of the most distant galaxies ever seen at the time. In the same year, he became the leading public spokesperson supporting continued operation of the Hubble Space Telescope following NASA's announcement that it would no longer service the telescope. The Ultra Deep Field remains the deepest picture of the universe, and the Hubble Space Telescope remains in orbit as one of NASA's most popular and scientifically productive spacecraft of all time, following a successful a servicing mission to Hubble in 2009.

He started his career as a member of the faculty at Cornell in 1978, remaining for their 13 years as a professor of astronomy. In 1991, he became a Director of the Max-Planck-Institut für Astronomie in Heidelberg, Germany with a staff of 200 and responsibility for the German National Observatory in Calar Alto, Spain. He returned to the United States in 1998 as the Director of the Space Telescope Science Institute in Baltimore, Maryland, where he was responsible for the science operations of the Hubble Space Telescope, and a professor of physics and astronomy at Johns Hopkins University. In 2008, he was appointed Vice President for Research and Graduate Studies at the University of California system-wide office, a newly created position within the UC system.

In addition to his work in research, he plays an active role in the management of UC's three laboratories for the Department of Energy, the Lawrence Berkeley, Lawrence Livermore, and Los Alamos National Laboratories, through the science advisory councils and the boards of directors. He also works nationally with the California and US governments and associations for higher education to promote research and graduate education in California and the United States.

Terry C. Wallace Jr.

As Principal Associate Director for Global Security (PADGS) at Los Alamos National Laboratory (LANL), Dr. Wallace leads laboratory programs related to national security Dr. Wallace leads laboratory programs related to national security. Los Alamos enhances our nation's security by developing and applying the scientific and engineering capabilities to counter threats, in particular those associated with weapons of mass destruction.

Dr. Wallace has served as Principal Associate Director for Science, Technology, and Engineering from 2006 to 2011, and as Associate Director of Strategic Research from 2005 to 2006. In those positions, Dr. Wallace integrated the expertise from all basic science programs and five expansive science and engineering organizations to support LANL's nuclear-weapons, threat-reduction, and national-security missions.

Dr. Wallace's expertise is forensic seismology, a highly specialized discipline focusing on detection and quantification of nuclear tests. His research has focused on measuring the effects and behaviors of explosive sources in complex environments, and assessing various geophysical signatures to determine explosive yields.

Raised in Los Alamos, Dr. Wallace served for 20 years as a professor of geosciences and an associate in the applied mathematics program at the University of Arizona. He returned to LANL in 2003 as Director of Los Alamos's Earth and Environmental Sciences Division. Wallace holds

Ph.D. and M.S. degrees in geophysics from California Institute of Technology and B.S. degrees in geophysics and mathematics from New Mexico Institute of Mining and Technology. Dr. Wallace is a Fellow of the American Geophysical Union (AGU), and in 1992 he received the AGU's Macelwane Medal. Dr. Wallace has served as President of the Seismological Society of America, Chairman of the Incorporated Institutions for Research in Seismology, and authored the position paper for the American Geophysical Union on the verifiability of a comprehensive test ban treaty. In June 2011, Dr. Wallace gained the rare honor of having a mineral named after him by the International Mineralogical Association Commission on New Minerals, Nomenclature and Classification.

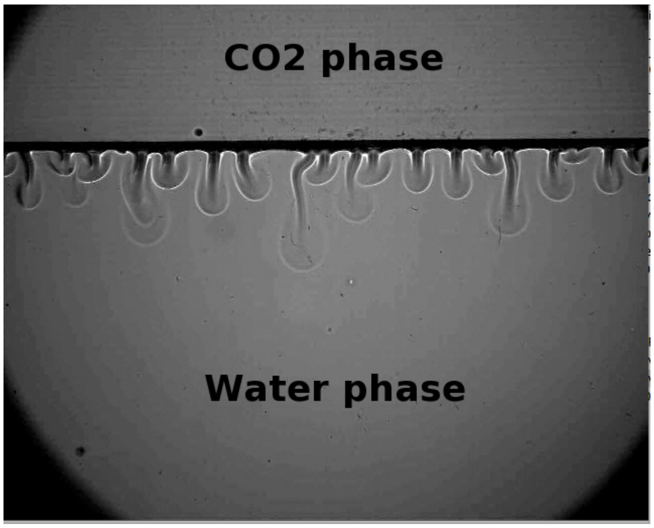
Energy Security
and
Technology Surprise

Poster Presentations

Permanent Storage of CO_2 from Fossil Fuel Emissions in Geologic Formations (Poster 1)

J. William Carey (PI), D. Newell, S. Backhaus, O. Kang, A. Abdel-Fattah, D. Moulton, M. Porter, P. He, E. Coon

Fossil fuels are the engine of today's economy as they are relatively inexpensive and convenient to use. However, the use of fossil fuels produces carbon dioxide (CO_2) and can have a profound impact on climate. In our project, we are developing an alternative to simply emitting CO_2 to the atmosphere: injecting the CO_2 waste stream into deep, permeable geologic formations for permanent storage. Our research involves studying the behavior of CO_2 as it flows through and reacts with rock. The goal is to use our findings to design the injection process to immobilize CO_2 and ensure safe and effective storage.



Photograph of experiment simulating the dissolution of CO_2 into water. The experiment explores the rate at which the CO_2 phase dissolves into the water phase, forming higher density fingers that descend into the "storage reservoir." The experimental system mimics the water-CO_2 system using propylene glycol for the water phase and water for the CO_2 phase.

Nanostructures for Solar Energy and Probing the Brain (Poster 2)

Shadi Dayeh (PI), Y. Hwang, J. Disterhaupt, J. Yoo, I. Campbell, J. George, S. Picraux

One of the current challenges in neuroscience is to develop long-term, high-fidelity neural interfaces for recording, stimulation, and drug delivery to control prosthetic devices for injured soldiers and disabled people. We must also understand the biological basis for out mental processes with an ultimate goal of controlling neurological disorders. In the seemingly unrelated arena of energy security, we are challenged with lowering the cost of high-performance solar cells. The fab-compatible nanostructures developed through our LDRD project enable viable solutions for both of these urgent problems.

Example of an prosthetic arm for injured army personnel.

Electrical Energy Storage (Poster 3)

Fernando Garzon (PI), A. Mueller, M. Sykora, J. Sansiñena, N. Henson, S. Kozimor, J. Boncella, R. Mukundan, I. Matanovic, A. Miglori, R. Borup

We are revolutionizing energy storage technology by developing the technical foundation for the conversion of electricity to liquid fuels. Energy storage technology is critical if the U.S. is to achieve widespread penetration of renewable electrical energy. Liquid fuels store energy at 100 times the density of batteries at a fraction of the cost. However, the economical conversion of electricity to fuel still presents significant technical challenges. We are addressing these challenges by focusing on a specific approach: efficient processes to convert electricity, water and nitrogen to ammonia. Ammonia has many attributes that make it the ideal energy storage compound. The feedstocks are plentiful, ammonia is easily liquefied and routinely stored in large volumes in cheap containers, and it has exceptional energy density for grid-scale electrical energy storage.

Liquid ammonia synthesis is a low cost and compact form of energy storage. The tank pictured at left stores 4 billion watt-hours of energy, enough to power over 100,000 households for a day.

Turning Sugars into Fuels: How Sweet It Would Be (Poster 4)

John Gordon (PI)

With decreasing global production of crude oil, it is essential to our national security that renewable alternatives to petrochemical feedstocks for hydrocarbon fuels are developed. A constant, reliable supply of these fuels would help ensure that the transportation of food, medicine, and consumer goods around the country remains uninterrupted, regardless of sociopolitical conflict. Lignocellulose is a promising carbon-neutral source of energy derived from wood, agricultural waste, and woody grasses. The carbohydrates D-glucose (C6), Larabinose (C5), and D-xylose (C5) are readily obtained from the hydrolysis of lignocellulose and constitute the most abundant renewable organic carbon source on the planet. Because they are naturally produced on such a large scale, these sugars have the greatest potential to displace petrochemical derived transportation fuel. We are investigating a potentially transformational strategy aimed at obtaining high energy-density hydrocarbon fuels from non-food based carbohydrate sources such as those shown in the figure below.

Carbohydrates can be accessed from non-food based biomass sources such as woody residues and switchgrass. Our goal is to convert these molecules into useful biofuels after they have been extracted from the plant source.

How Do Soil Bacteria Respond to Climate Change? (Poster 5)

Cliff Han (PI), A. Dichasa, J. Berendzen, C. Kuske, B. Stevens, B. McMahon, P. Chain, A. Bradbury, J. Cohn, N. Hengartner

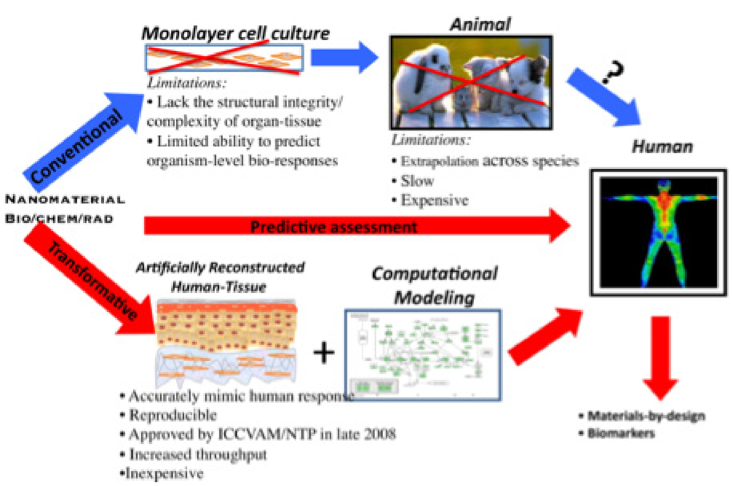
Soil microbes live in a super complex community with millions to billions of bacterial cells per gram of soil. Our study will help us understand how climate change will impact different bacterial species. We are developing technologies to answer three basic questions about microbial communities in any environment with an arid soil community as an example: Who is there? What they are doing? How do they interact with each other?

Field site at Moab, Utah for studying microbial community in arid land. Changes of temperature and precipitation are applied to the experimental site to identify responses from the microbes.

Rapid Bioassessment of Engineered Nanomaterials (Poster 6)

Rashi Iyer (PI), J. Hollingsworth, S. Iyer, J. Gao, A. Nagy, T. Sanchez, H. Wang, J. Song

Engineered nanomaterials (ENM) have found applications in biomedicine, national security and the food industry. The current lack of understanding of interactions between ENMs and biological systems raises uncertainties about the long-term health and environmental impact of these materials, consequently, limiting their applications. The sheer diversity of nanomaterials, compounded by the lack of relevant screening platforms present unprecedented challenges in determining their safety and efficacy. Our focus is to develop human-relevant 'bench-top' experimental platforms that will enable high-throughput and rapid assessment of these man-made materials, enabling the expeditious use of nanomaterials to meet the needs of the 21st century.



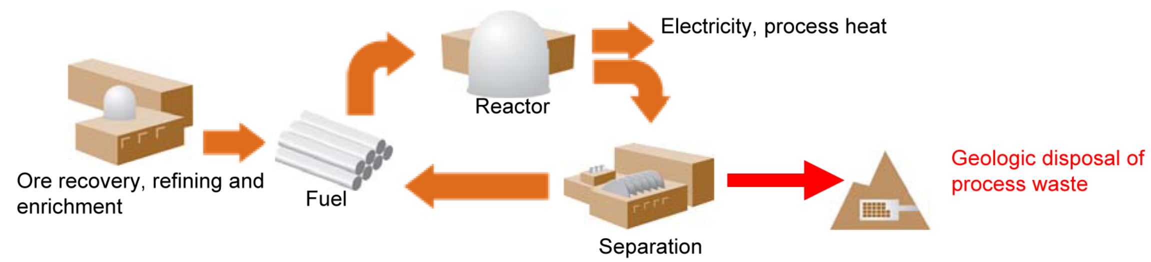
Transformative approach to bioassessment of engineered nanomaterials.

Enabling Solutions to the Nuclear Waste Problem (Poster 7)

Chris Stanek (PI), B. Uberuaga, B. Scott, L. Wolfsberg, W. Taylor, M. Nortier, N. Marks

Nuclear waste disposal is a significant technological issue. The solution to this problem will ultimately determine whether nuclear energy is deemed environmentally acceptable. The design of robust nuclear waste forms requires consideration of several criteria, but historically, relatively little attention has been paid to the durability of candidate waste forms during the course of daughter product formation; that is, its radioactive transmutation into new elements with different chemistry. We highlight the research challenges associated with understanding waste form stability and present recent experiments and atomic scale simulations on isotopically pure samples, which yield unexpected results.

Full Recycle (Fully Closed)

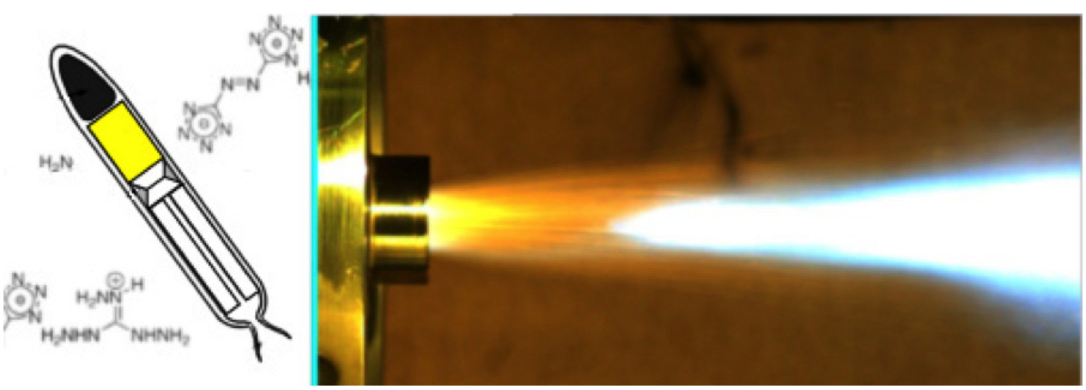


A schematic representation of a full-recycling closed fuel cycle, as envisioned by the U.S. Department of Energy, where the red arrow denotes the requirement of customized waste packages for individual fission products.

Next-generation Solid Rocket Propulsion System (Poster 8)

Bryce Tappan (PI), G. Risha, A. Novak, E. Baca, M. Short, D. Oschwald

Solid propellant systems have proven reliable over the decades but have reached their limit in terms of system safety and performance. Still, demand for higher-performance systems with an increased level of safety still exists. However, getting both increased safety and higher performance is difficult and higher-performance systems are generally higher hazard. The goal of the current research is to develop a propellant system based on high-nitrogen/high hydrogen energetic fuel that can burn separately from solid oxidizers. This separation of the fuel and oxidizers could provide a break-though to the next generation of solid rocket propellants with increased safety and performance.



Conceptual rocket motor, left, showing energetic solid fuel (yellow) in tandem with solid oxidizer (white) and static test of the system, right, in a 12.7 mm motor.

Defense Against Nuclear Threats

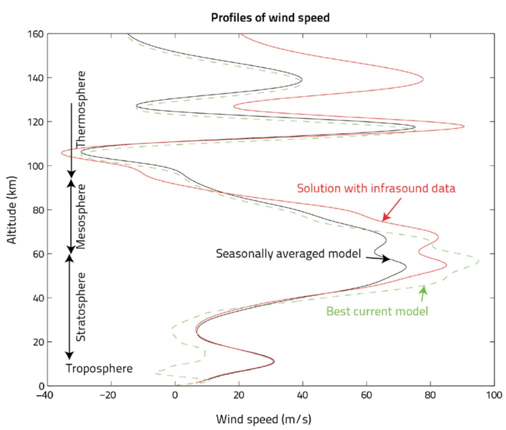
Poster Presentations

Using Low-frequency Sound to Measure Winds in the Stratosphere (Poster 9)

Stephen Arrowsmith (PI), O. Marcillo

Recent studies by climate scientists suggest that knowledge of the temperatures and winds in the stratosphere, and how these are changing with time, may be critical for understanding and forecasting climate change. The problem is that measuring winds in the stratosphere is very challenging. At present, we rely upon measurements from rocket launches and a limited set of laser-based ground sensors (LIDAR sensors) for direct measurements of winds in the stratosphere. Unfortunately, in addition to the high expense, both rockets and LIDAR measurements can only provide measurements for limited regions of space and/or time. Furthermore, LIDAR measurements are typically only made during nighttime.

Low-frequency sound below the threshold of human hearing, called infrasound, can travel long distances through the Earth's atmosphere by refracting multiple times in the stratosphere. A wide variety of sources can generate infrasound including ocean waves, meteoroids, volcanoes, explosions, and earthquakes. Because infrasound propagates through the stratosphere, temperatures and winds at those altitudes affect it. We have developed a new way to use these sources of sound in order to measure wind speed in the stratosphere with low-frequency microphones. In contrast to existing techniques, our technique can record continuously over a single location using infrasound from ocean storms. In this poster, we discuss how we use infrasound to measure wind speeds in the stratosphere, then demonstrate how the technique works using infrasound from a meteoroid that entered Earth's atmosphere over the North Pacific.

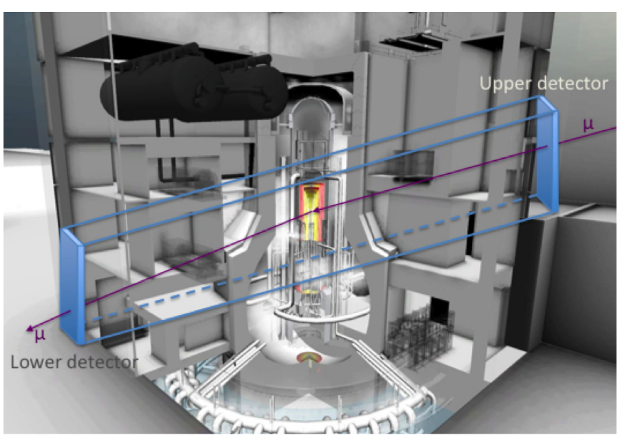


Using data from a meteoroid that fell through the atmosphere on Christmas day, 2010, we have improved upon a seasonally averaged model of the wind in the stratosphere (black line). Our final solution using the seasonally averaged model as the starting model (red line) is more similar to the best estimate from ground and satellite data (best current model - green dashed line) in the stratosphere.

Imaging Nuclear Power Reactors with Cosmic-ray Muons (Poster 10)

Konstantin Borozdin (PI), J. Bacon, R. Busch, K. Carpenter, E. Chen, A. Hecht, C. Milner, H. Miyadera, C. Morris, J. Perry, J. Roybal, C. Spore, N. Toleman

We have developed a technique to image and identify unknown materials using muons – subatomic particles produced by the interactions of cosmic rays in atmosphere. Our technique measures the scattering of muons with particle detectors to determine density and generate images of the objects. One example of planned implementation of muon tomography is the imaging of the damaged reactor cores at Fukushima Daiichi. To demonstrate the capability, we will image a core of the research reactor at the University of New Mexico. Muon Tomography is perhaps the only viable way of imaging such reactor cores from outside of the reactor radiation shielding.



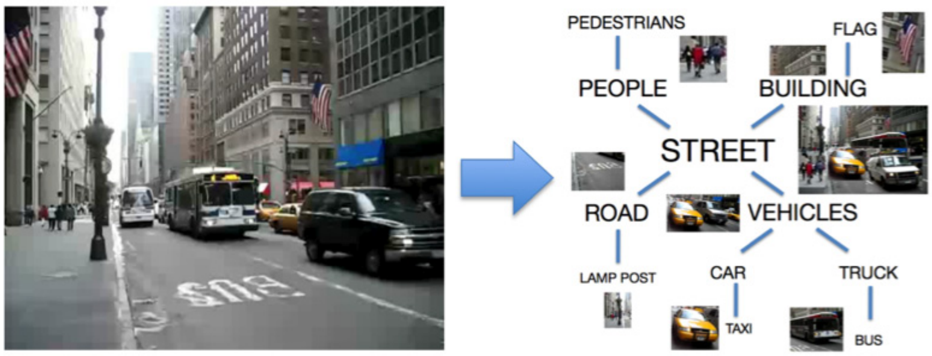
Concept of reactor core imaging with cosmic rays. Two cosmic-ray detectors (shown in blue) would be installed on opposite sides of the reactor building to assess the damage to the core (the melted core is shown in yellow and red). The three-dimensional visualization of the Fukushima Daiichi reactor #1 is done by the VISIBLE team at LANL.

Human-like Computer Vision Using Deep, Sparse Models (Poster 11)

Steven Brumby (PI), R. Chartrand, A. Galbraith, N. Hengartner, Z. Ji, G. Kenyon, D. Moody, D. Paiton, J. Theiler, M. Warren, B. Wohlberg

At any given moment, our visual environment contains hundreds of objects drawn from tens of thousands of object categories. What kinds of computing platforms are needed to run these algorithms at real-time processing rates? How can these algorithms learn from mostly unlabeled data, and generalize to include novel objects or to detect surprising combinations of objects?

We present results from our project exploring human-like computing vision algorithms based on recent breakthroughs in mathematical signal processing theory and in data-intensive supercomputing technologies. The idea is that video sequences of natural scenes are highly structured, and can be described in terms of a few objects (e.g., a dog and a child running in a park). Sparse representations provide a precise mathematical framework for representing such scenes, and deep generative statistical models provide a natural and robust framework for learning and reasoning about these models.

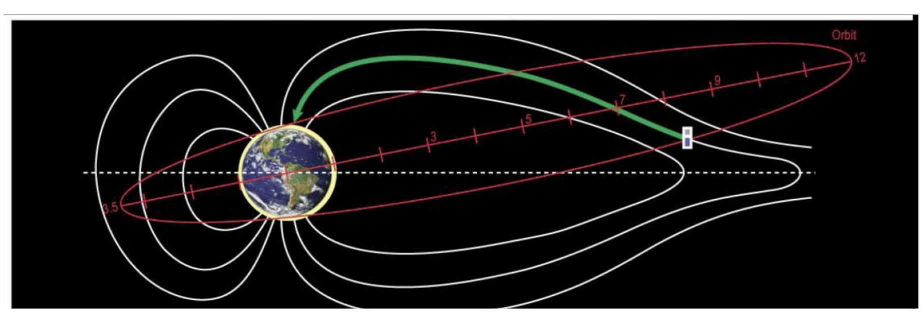


Natural video sequences contain hundreds of objects from thousands of possible object categories. Deep, sparse generative models provide a precise mathematical framework for learning and reasoning about visual environments, and these models can be given real-time software implementations using super-computing resources.

Probing the Earth's Magnetosphere with an Electron Gun (Poster 12)

Gian Luca Delzanno (PI), E. Camporeale, J. Borovsky, E. MacDonald, M. Thomsen

We are exploring the possibility of emitting a stable, high-intensity electron beam from a magnetospheric spacecraft, overcoming enormous spacecraft-charging problems. A successful outcome would enable a new class of space missions aimed at probing dynamic magnetospheric processes by direct mapping of magnetic field lines (through the electron beam) over vast regions of near-Earth space. In this poster, we will discuss the general problem, the road-blocks that have so far impeded the development of this technique, our proposed solution, and what we are doing to prove the feasibility of our idea, including the development of unique, state-of-the-art computational tools.

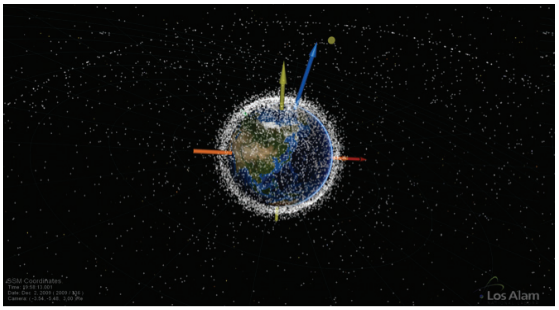


The ConnEx proposal: dynamic processes in the Earth's magnetosphere can be probed by tracing magnetic field lines with an electron beam emitted from a spacecraft.

Avoiding Collisions in Space (Poster 13)

Josef Koller (PI)

The United States relies heavily on its space infrastructure for a vast number of applications, including communication, navigation, banking, national security, and research. However, NASA predicts that between now and 2030 orbital collisions will become increasingly frequent and could reach a runaway environment. This devastating scenario, also known as the Kessler Syndrome, will eventually destroy our assets in near Earth space and result in a debris cloud that could make space itself inaccessible. Preventing the Kessler Syndrome requires a ground-breaking new orbital dynamics framework that combines a comprehensive physics-based model of atmospheric drag with an accurate uncertainty quantification of orbital predictions. To achieve this goal, we are developing and calibrating a new physics-based atmospheric dynamics model that is driven by space weather and suitable for orbital drag calculations. Our physics model will be based on a 3-D coupled ionosphere-thermosphere model solving the full Navier-Stokes equations for density, velocity and temperature for a number of neutral and charged components. This will allow us to study in detail the complex energy absorption of solar UV photons, deposition and Joule heating by precipitating particles, global redistribution and cooling. In addition to a new physics-based atmospheric density model, we will advance the field by providing accurate uncertainty quantifications of orbital predictions obtained using a full probability distribution in place of a limiting Gaussian assumption. Results from this work will be highly relevant for satellite operations and space traffic control.

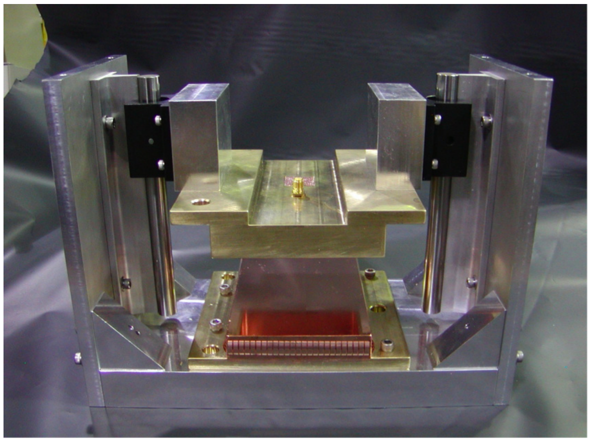


Space is congested, contested, and competitive. This figure shows cataloged position of about 15,000 space objects. We estimate there are ~½ Million objects in orbit with the size of a marble or larger. All these object are potentially harmful to our space assets as they travel at very high speeds of 7 km/s and faster.

Nonlinear Materials for High-power Microwave Devices (Poster 14)

Quinn Marksteiner (PI), C. Chen, B. Haynes, D. Dalmas, D. Shchegolkov, M. Treiman, E. Pulliam

Barium Strontium Titanate (BSTO) ceramics have many interesting properties, including ferroelectricity, high permittivity, and nonlinear dependence of permittivity on applied electric field. The nonlinearity of these materials can be used in a nonlinear transmission line (NLTL), which is a compact device that can be used to generate high power microwave (HPM) radiation in the GHz frequency range. These devices have the potential to revolutionize radar, communications systems, and other devices that use high power microwaves, because they are compact, solid state, and tunable. While a NLTL can be very efficient in theory, attempts to implement an NLTL from our nonlinear materials in the past have failed because the materials were too lossy (the energy converted to heat instead of microwave radiation). We will present the progress we have made in solving these problems.



The resonant cavity used to measure the high frequency properties of the nonlinear materials.

Rusty Metal Absorbs Trace Plutonium from the Environment (Poster 15)

Warren J. Oldham, Jr. (PI), B. Matteson, J. Miller, J. Berger, R. Gibson, M. Attrep, Jr.

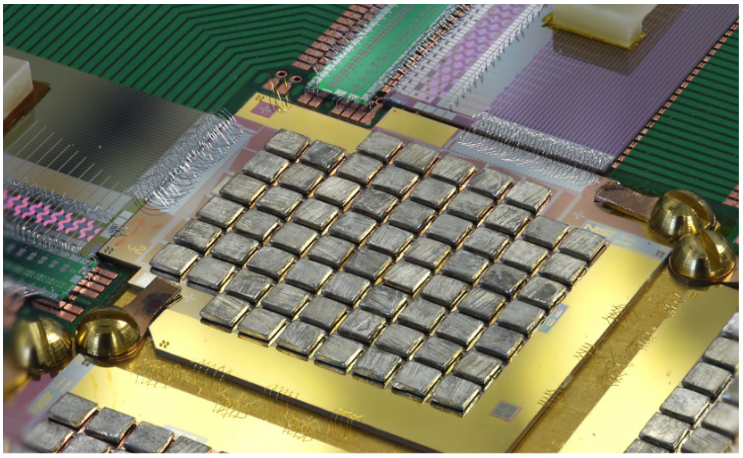
Trace levels of plutonium inadvertently released into the environment during various nuclear activities can be difficult to detect and even harder to interpret. This research is directed toward solving problems in nuclear proliferation monitoring and detection, where only analytical measurements of environmental samples are available for interpretation. Our work has shown that discarded rusty metal objects, such as bottle caps and common nails, adsorb and concentrate trace levels of actinides within the surface oxide coating during environmental exposure and weathering. This surprising observation is being developed for ultra-low detection and characterization methodology for applications in nuclear forensics.

Discarded rusty iron objects adsorb and concentrate trace levels of plutonium and other actinide elements within the surface oxide coating during environmental exposure. This technique is being used to identify and characterize signatures that date from the Manhattan Project in comparison to the regional background resulting from atmospheric nuclear testing.

Ultra-cold Sensors for Nuclear Safeguards and Forensics (Poster 16)

Ryan Winkler (PI), M. Croce, A. Hoover, G. Kunde, M. Rabin, J. Ullom, D. Bennettt, W. Doriese, J. Fowler, R. Horansky, D. Schmidt, L. Vale

Radiation detectors based on transition-edge sensors, essentially highly sensitive temperature-dependent resistors, display extraordinary promise in Nuclear Safeguards and forensic applications. These microcalorimeter sensors are capable of the detection of a variety of radiation types over large energy ranges with remarkable resolution. Arrays of these detectors are currently utilized for the high-precision measurements of X- and gamma-rays emitted from materials containing radioactive Actinides pertinent to Nuclear Safeguards applications. In the field of nuclear forensics, the ultra-high energy resolution capabilities of microcalorimeter detectors for alpha-decay spectroscopy allow for significantly improved analyses of trace quantities of radioactive material.



A portion of an array of microcalorimeter detectors with attached high-purity Sn absorbers used for the detection of X- and gamma-rays with remarkable energy resolution.

Ticking Nuclear Clocks (Poster 17)

Xinxin Zhao (PI), Y. Martinez De Escobar, B. Rundberg, E. Bond, A. Moody, T. Bredeweg, M. Wilkerson, B. Barker, D. Vieira

Clocks are everywhere in our daily lives. Every clock has a timekeeping oscillator like a quartz crystal in a quartz watch. Today, the most accurate clocks are atomic clocks based on the oscillation of electrons. They are ticking in many time-critical places such as Global Position System satellites that guide missiles, planes, and automobiles. A "nuclear clock," based on the collective beat of protons and neutrons in a thorium-229 nucleus, promises 100 times better accuracy than the best atomic clock. We will present our research on thorium-229 for the development of an ultimate time machine.

Win the gold by 0.0000000000000000001s in the age of nuclear clocks (powered by LANL Th-229 chip inside).

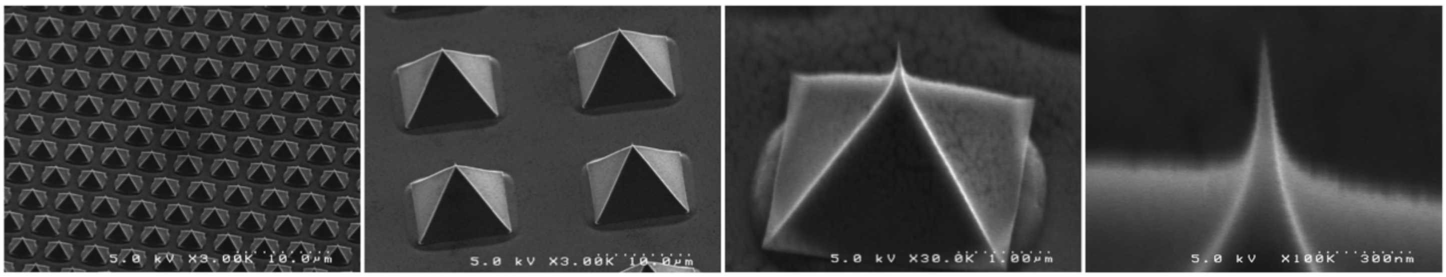
Stockpile Stewardship

Poster Presentations

Cheaper Electrons for Electronics (Poster 18)

Heather Andrews (PI), C. Brau, W. Gabella, B. Chai

Electron beams lie at the heart of many technical systems, from x-ray tubes to satellites. Existing sources of electrons, called cathodes, are limited in robustness, lifetime, and in the quality of electron beam they can produce. If we could develop a cathode with a longer lifetime, the satellites relaying music and television would last longer and cost less. We are investigating a new type of diamond cathode that consists of an array of exquisitely sharp pyramids. These cathodes have shown promise of increased robustness and lifetime, but to benefit scientific applications we must scale them to produce short electron bunches and high current density. Devices ranging from high-resolution displays and rf sources in satellites to research equipment like X-ray sources and electron microscopes will benefit from robust cathodes that emit high quality electron beams.

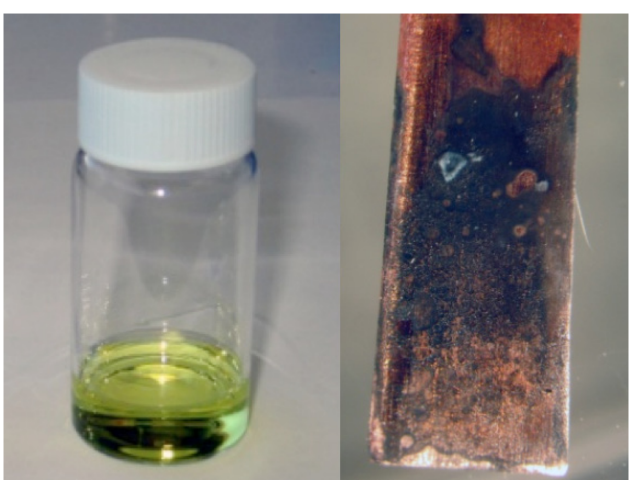


A diamond pyramid array (DFEA) cathode shown at four different magnifications. The sharpened pyramid tip is the same size as a carbon nanotube, about one millionth of a millimeter (this line is one millimeter long).

Ionic Liquids for Advanced Nuclear Fuel Cycles (Poster 19)

George Goff (PI), X. Chen, W. Ewing, K. Long, B. Carney, B. Scott, G. Jarvinen, W. Runde, D. Fagnant Jr., J. Brennecke

The renewed interest in increasing nuclear energy to sustain current and future energy needs around the globe includes the search for revolutionary technologies for advanced nuclear fuel cycle options. Ionic liquids (ILs) are low-melting salts, and are of particular interest because they offer a wide range of tunable physical properties, including vapor pressure, viscosity, hydrophobicity, and electrochemical windows. The behavior of actinides in ionic liquids is currently not understood. We will present recent results in our efforts to understand actinide chemistry in ILs and to demonstrate the feasibility of using ILs for advanced actinide separations.

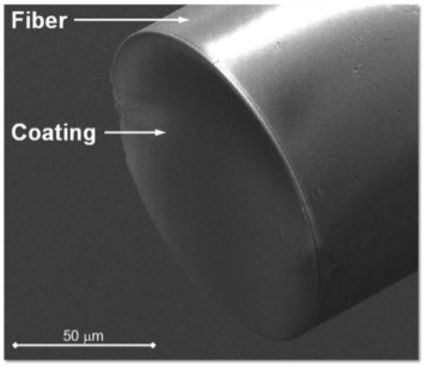


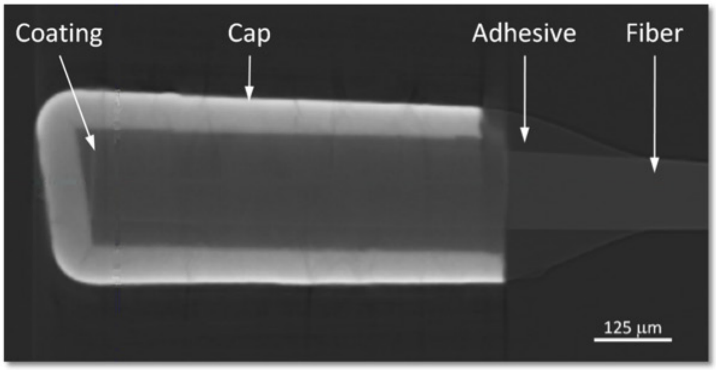
Uranium dissolved in the ionic liquid propylmethylpiperadinium bistriflimide (left), which was used to electrodeposit UO_2 onto a copper electrode (right).

Measuring Pressure and Temperature Inside a Thermal Explosion (Poster 20)

Markus P. Hehlen (PI), L. Smilowitz, G. Parker, A. Novak, M. Holmes, K. Henderson, G. Rivera, D. Schmidt

The conditions inside an explosion are extreme. Temperatures over 1000 oC and pressures over 100,000 psi can develop within just a few millionths of a second. Knowledge of temperatures and pressures is critical to our understanding of the performance and safety of high explosives. No such thermometers or pressure gauges exist today. We are developing a new family of sensors that can measure temperature and pressure using light. These miniature sensors will allow us to probe the conditions inside a thermal explosion for the first time and shed light on the complex processes that occur during such a violent event.



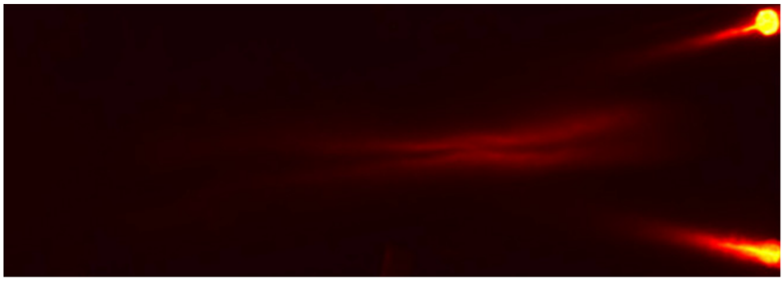


Specialized coatings are deposited onto optical fibers (left) which are assembled into miniature sensors (right) that can measure temperature and pressure inside a thermal explosion.

Making Astrophysical Shock Waves in the Laboratory (Poster 21)

Auna Moser (Presenter), Scott Hsu (PI), C. Adams, C. Thoma

Explosions and high-speed impacts in space produce a special type of shock wave: particles in the shock do not collide with each other as required for shock formation on Earth; instead particles interact with electromagnetic fields to create "collisionless" shock waves. Details of how collisionless shocks form, and how they produce high-energy particles called cosmic rays, remain mysterious. We are attempting to generate collisionless shocks in the laboratory by direct impact of two supersonic plasma jets, both to learn more about collisionless shock formation and to search for shock acceleration of particles, an often-cited process that has never been directly observed.

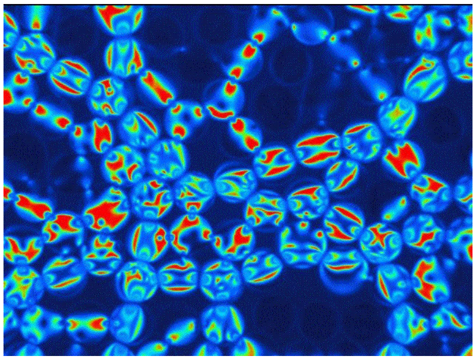


Left: A shock wave forms as material flows around a young star. Plasma flowing by the star at high speed (from image-right to image-left) collides with the star's solar wind, creating a curved, collisionless shock wave. Image credit: NASA and The Hubble Heritage Team (STScI/AURA). Right: Preliminary impact experiments in the laboratory show a bright interaction region between two merging plasma jets. Future experiments will produce collisionless shocks via head-on impact of two such high-speed plasma jets.

What Triggers an Earthquake? (Poster 22)

Paul Johnson (PI), R. Ecke, E. Daub, E. Ben-Naim, C. Wu, C. Reichhardt, S. Backhaus, T. Salah, C. Marone, J. Carmeliet, R. Guyer, J. Gomberg, M. Griffa, B. Ferdowsi

In 1992, a very strong earthquake of Magnitude (M) 7.3 occurred in Southern California near the town of Landers. This earthquake demonstrated a remarkable phenomenon: as seismic waves radiated from the event, other earthquakes were *dynamically triggered,* not only nearby but as far as 1000 km away, and elevated seismicity, termed *delayed triggering*, lasted for at least several months. Recent observations based on rapidly improving instrumentation show that a significant number of earthquakes are dynamically triggered. *That a large percentage of earthquakes are dynamically triggered provides a path towards a profound advance in seismology and earthquake hazard assessment.* The traditional description of earthquakes relies on the classical plate-tectonic model of passive plates driven by mantle convection where stresses build up at locked-plate contacts that abruptly slip, leading to an earthquake caused by local stress conditions. The paradigm of dynamic earthquake triggering suggests a radical new understanding of earthquakes, implying that Earth's elastic system is far more complex than previously imagined with substantial long-range interactions among faults. In particular, dynamic stress from seismic waves can perturb fault systems that are in a critical state and force failure earlier in time relative to an unperturbed fault. *Earthquake physics and hazard must be rethought, and we are attempting to do just that.* Our ultimate goal is to obtain characteristic time intervals of increased earthquake probability for particular faults in the Earth. *We are not proposing to predict earthquakes, but to work toward predicting intervals of increased hazard.* Because large earthquakes pose serious risks to national energy and economic security, the proposed work could have enormous societal impact by forecasting the imminence of these events.

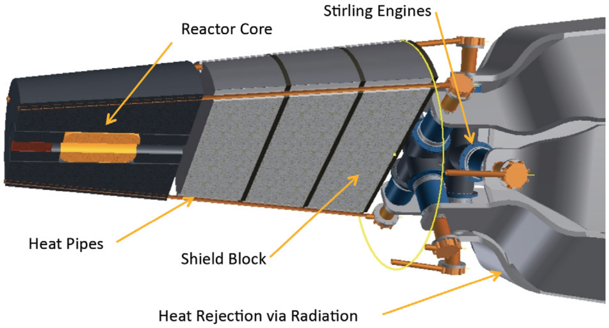


The inside of a fault contains fault gouge, created by the crushing and grinding of fault blocks as they slip past each other over the eons. The gouge strength is carried by the 'force chains' — the brightly colored chains in the figure.

Small Reactors for Space Exploration (Poster 23)

Patrick R. McClure (PI), D. Poston, D. Dixon, R. Reid, R. Sanchez, T. Beller, M. Gibson, O. Mireles

Los Alamos National Laboratory (LANL), the National Aeronautics and Space Administration (NASA), and National Security Technologies have teamed together to demonstrate the concept of a very small reactor for NASA deep space missions. The small reactor would be very simple and would work using heat pipes, Stirling engines and basic reactor physics. Heat pipes are mainstream products used in applications like laptops. Stirling engines are an old technology modernized by NASA. LANL has coupled these items to produce a small reactor concept. This concept is being demonstrated in Nevada using nuclear material, that can go critical (i.e. fission), to drive a heat pipe coupled a Stirling engine to produce electricity.

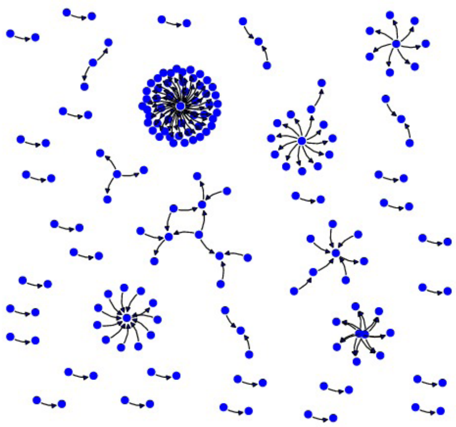


Artist's conception of a small fission reactor with heat pipes and Stirling engines.

Cyber Security Science (Poster 24)

Joshua Neil (Presenter), Mike Fisk (PI), S. Eidenbenz, A. Hagberg, B. Anderson, H. Djidjev, J. Howse, C. Storlie, G. Yan

Computers are ubiquitous in modern society. They facilitate our everyday communication and control the cyber systems that run our nation's critical financial, energy, and defense infrastructure. Still, major computer break-ins are a regular occurrence. The challenge to provide robust and secure cyber systems is increasing. To address this challenge we are developing a network science approach to cyber security that seeks foundational principles of cyber communication. This approach exploits our ability to acquire and analyze large data sets that are unique to the LANL environment to develop statistical models of system connectivity. These models allow the design of network-scale methods for detecting adversaries in complex networked cyber systems.

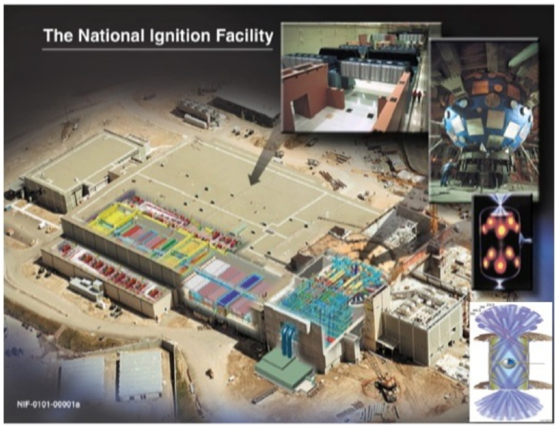


A graph-based view of LANL network connections.

Using the National Ignition Facility to Better Understand Materials Mixing (Poster 25)

Mike Steinkamp (PI), R. Gore, G. Grim, G. Jungman, M. Boswell, J. Fincke, A. Hayes-Sterbenz, A. Klein

Energy demands increase with the world's standard of living. With increased energy usage comes problems of supply and pollution. Inertial Confinement Fusion (ICF) is a technology that will hopefully someday offer vast amounts of clean energy. Someday ICF will produce energy by blasting small National Ignition Facility (NIF) fuel capsules with hundreds of focused lasers. However, there are many technical issues to solve before ICF is a viable clean-energy option. One huge ICF problem is how two adjacent capsule materials mix together after being slammed (shocked) by a laser. In this project, we use computer codes and high tech equipment to study this mixing problem.



The National Ignition Facility (NIF), completed in Jan 2009, is located at Lawerence Livermore National Laboratory. The facility contains 192 laser beams, capable of delivering 1.8 Mega Joules (351 nanometer) at 500 TeraWatts. Pic-in-Pick, clockwise left to right detail the (a) the laser bay, (b) the target chamber, and (c) and (d) the laser/holraum configuration.

Discovery Science

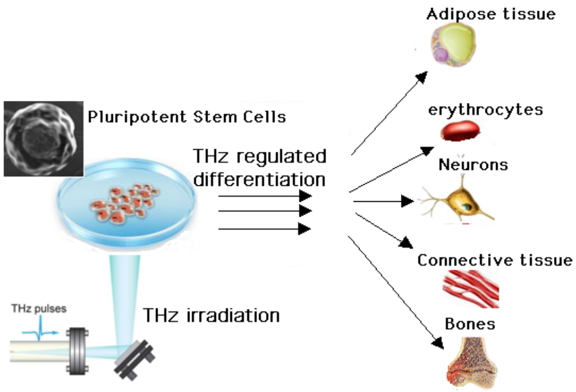
Poster Presentations

Breathing, THz Radiation, and DNA Biological Functions (Poster 26)

Boian Alexandrov (PI), J. Martinez, G. Rodriguez, A. Usheva, K. Rasmussen

In the living cell, the double-stranded DNA molecule experiences thermal motions that induce spontaneous openings and re-closings of the double helix known as “DNA breathing.” The propensity for this breathing is connected with the molecule’s local flexibility and plays key role in DNA biological functions. Our research shows that DNA breathing is directly associated with reading genetic code, DNA-protein interactions, and participates in genetic disease mechanisms.

We have demonstrated that, by affecting DNA breathing, electromagnetic terahertz radiation can influence gene expression and can be used for stem cell reprogramming. Understanding this phenomenon has the potential to enable active control of gene expression and cell differentiation. An ability to activate specific genes will have tremendous technological and economic impact in industries that rely on protein or lipid production. Similarly, control of cell differentiation (i.e. the technology to produce specialized cells such as those in bone, cartilage, retina) would revolutionize regenerative medicine and offer great hope in the battle against devastating diseases.

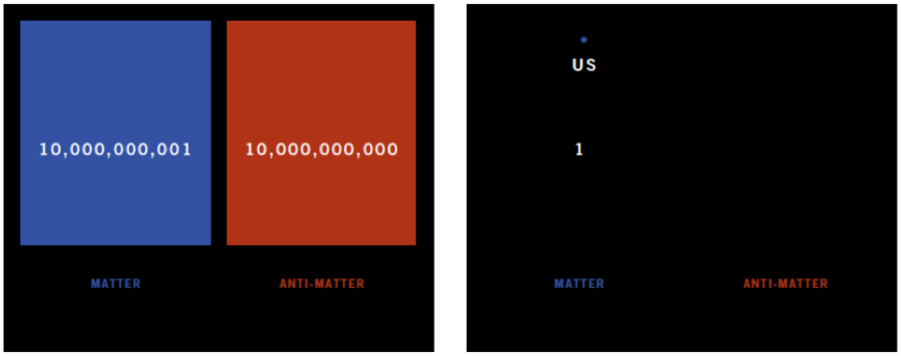


Leveraging terahertz radiation (THz) for accelerating stem cells differentiation to various tissues. Although the tissue penetration of THz radiation is limited, understanding of the interaction between THz radiation and stem cells (the body’s “injury drugstore“) could directly lead to new treatment advances for diseases such as melanoma and esophageal cancer, whose locations are directly reachable by THz radiation. Another example of a potential therapeutic application of THz radiation is the treatment for surface lesions - wounds, burns, ulcers, etc.

Why is the Universe Made of Matter? (Poster 27)

Vincenzo Cirigliano (PI)

In the primordial soup one microsecond after the big bang there must have been a tiny imbalance of one part in ten billion between matter and antimatter. As the Universe cooled down, matter and antimatter annihilated, leaving the tiny initial excess of matter to form the observed stars. The mechanism that generated this asymmetry remains unknown. Through theoretical calculations and numerical simulations, this project sheds light on a very attractive mechanism, testable by combining searches at the Large Hadron Collider with a LANL-led neutron experiment at Oak Ridge National Laboratory.

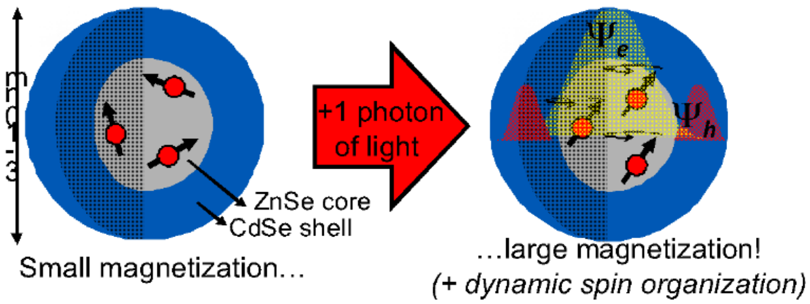


The early universe (left). When matter and antimatter annihilated at the big bang, some tiny asymmetry produced our universe as we know it today (right), made entirely of matter.

Flipping the Light Switch on Nanometer-scale Magnets (Poster 28)

Scott Crooker (PI), V. Klimov, J. Pietryga, H. McDaniel, S. Brovelli

In this project we are developing and investigating a new class of nanometer-scale materials that exhibit "persistent photo-magnetization". That is, these new materials actually become more magnetic when illuminated with light -- in marked contrast with ordinary magnets. These materials are tiny nanocrystals containing only about 1000 atoms of the semiconductor zinc-selenide, and within these nanocrystals we incorporate, using chemical synthesis, a handful of copper atoms (anywhere from zero to about five copper atoms). The resulting interplay between photons (light), the semiconductor, and these copper atoms can actually increase the number of copper atoms that behave magnetically.

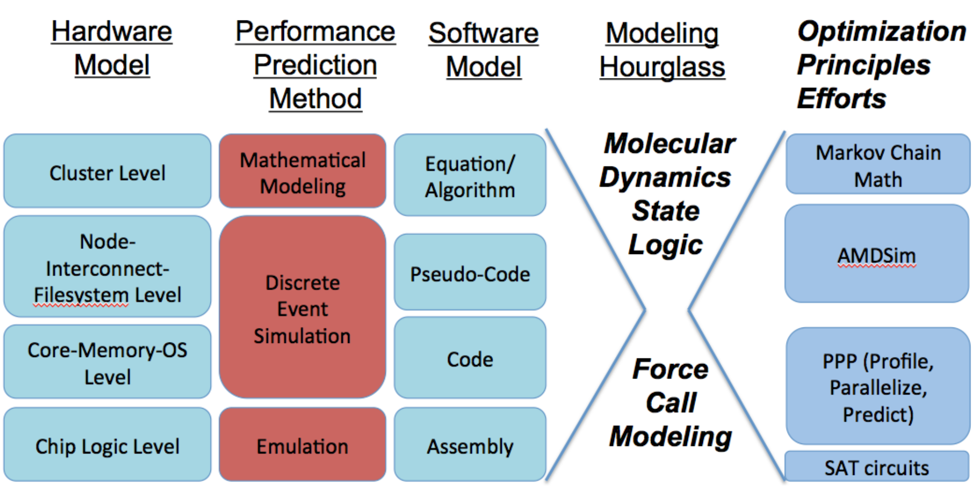


These schematics depict the copper-doped ZnSe semiconductor nanocrystals. Addition of one photon of light excites one electron (and one hole) into the nanocrystal, which in turn organizes and increases to total magnetization of the copper atoms.

Computational Co-design: Matching Computer Designs with Computer Programs (Poster 29)

Kei Davis (Presenter), Stephan Eidenbenz (PI), A. Voter, C. Junghans, S. Mniszewski, D. Perez, N. Santhi, S. Thulasidasan

Computational co-design is coordinated design of two or more components of a computational system; for example, an algorithm (computer program) and the hardware (computer) it is to run on. The two are mutually tailored to each other for maximum performance and cost-effectiveness. This project is developing a methodology for formally characterizing co-design--normally an ad-hoc and labor-intensive process--as a mathematical optimization problem amenable to automated solution. For test cases we are using applications in molecular dynamics, a science area with many important applications including design of new manufactured materials and therapeutic drugs.



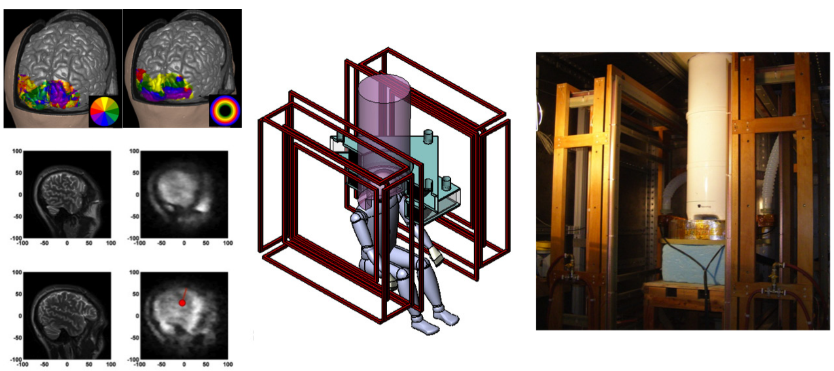
Hardware-software co-design spans hardware and software descriptions from high to low levels, requiring multiple analysis techniques.

Ultra-low Field MRI: Seeing Vision in Action (Poster 30)

Michelle Espy (PI), E. Burmistrov, J. George, A. Guthormsen, P. Magnelind, A. Matlashov, H. Sandin, A. Urbaitis, P. Volegov

Experiments have shown that there are measurable neurological signals associated with visual cognition (defined behaviorally as when the subject recognizes the target). However, due to limitations in present non-invasive functional brain imaging methods, these experiments can presently only answer the “when” or the “where” of visual cognition, but not both at the same time. Without this ability, many critical questions about how the brain works remain unanswered.

Techniques such as magnetic resonance imaging (MRI) provide excellent spatial information (where), but limited temporal information (when) about brain function. Methods such as magnetoencephalography, (MEG), provide excellent temporal information via measuring the magnetic fields produced by neuronal firing, but have limited spatial information. LANL presently leads the world in a technique called ultra-low field (ULF) MRI which uniquely enables us to do both MRI and MEG in a combined approach. By combining novel magnetic field pulsing with ultra-sensitive detection, ours is the only approach capable of combining the anatomical specificity of MRI with the high temporal resolution of MEG to *measure both the dynamics and origin of cognition*. The method may also provide entirely new ways to image brain activity.

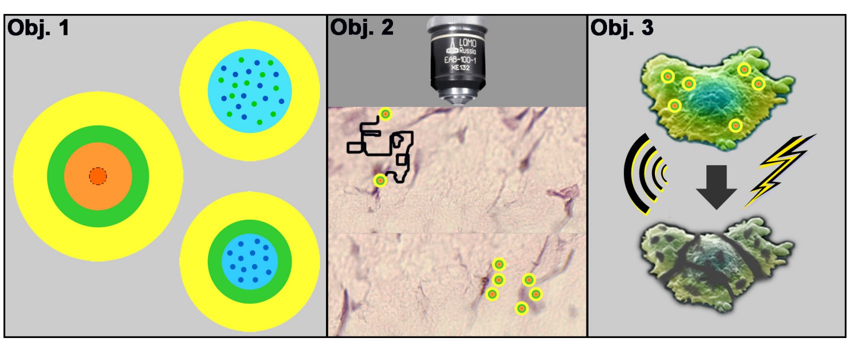


Using conventional high field fMRI, we have identified specific regions of visual cortex (retinotopic mapping) using a rotating checkerboard stimulus. The fMRI activity in response is shown superposed on the head. These data will help focus our in the ultra-low field (ULF) MRI/MEG system (shown schematically at center).

The Path to Nanoparticle Cancer Drugs (Poster 31)

Jennifer Hollingsworth (PI), J. Werner, R. Iyer, N. Karan, A. Keller, A. Nagy, Y. Ghosh, J. Casson

In contrast with small-molecule chemotherapy drugs, nanoparticle-based therapies promise fewer side effects and improved performance. Traditional therapies attack both cancerous and healthy cells indiscriminately, which can lead to drug resistance, and often force physicians to back off on doses. Nanoparticles promise direct delivery of therapeutic agents to the cancer tumor. However, accurate targeting demands alternative, multi-functional nanoparticles. We aim to develop and test novel “inverted” nanoshell nanoparticles to provide the required combination of functionalities: imaging, so they can be tracked to the tumor, and selective therapy.



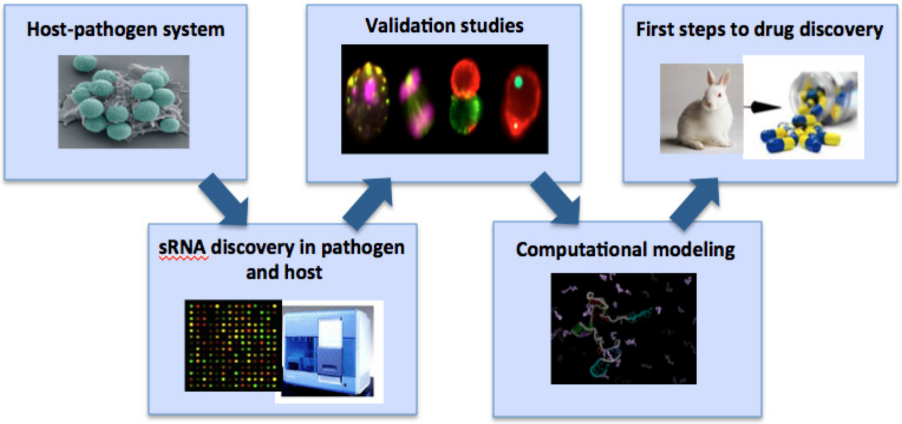
Project objectives include, 1) inverted nanoshell design and synthesis, 2) deep-tissue imaging and tracking, and 3) proof-of-concept cancer-cell targeting and photothermal.

Putting “Useless” DNA to Use (Poster 32)

Elizabeth Hong-Geller (PI), K. Sanbonmatsu, P. Chain, J. Werner

One of the greatest mysteries in modern molecular biology is the functional role of the 3 billion DNA bases in our genome. Based on the Human Genome Project, only about 2% of our DNA are predicted to be genes that encode for proteins. The remaining 98% was labeled “junk DNA” to connote that inter-genic DNA had no useful function. However, in the last decade, scientists have discovered that “junk DNA” encodes for small RNA (sRNA) molecules, a new class of regulatory biomolecules that control key cellular functions and is found in diverse organisms, from bacteria to plants to man.

We are applying sRNA function discovery to a daunting public health challenge. The rampant use of antibiotics in the last half-century has imposed an unforeseen biological cost, the unprecedented acceleration of bacterial evolution to produce drug-resistant strains to practically every approved antibiotic. This rise in antimicrobial drug resistance, alongside the failure of conventional research efforts to discover new antibiotics will eventually lead to a public health crisis that can drastically curtail our ability to combat infectious disease. In this project, we are discovering sRNAs that function in the virulence of *Yersinia pestis*, the causative agent of plague, as a means to identify sRNA targets for anti-microbial therapeutic development.

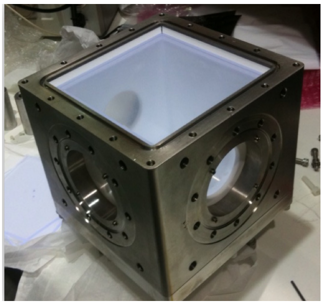


Pipeline development for discovery of host and pathogen small RNAs as novel signatures for therapeutic development, bioforensics, and pre-symptomatic detection.

Ultra-cold Neutron Decay: A Window into the Unknown (Poster 33)

Mark Makela (PI), V. Cirigliano

This project combines theoretical and experimental efforts to look for evidence of particles and interactions we have not seen yet. New experiments in this area help theorists create more exact models of our universe and its creation. The experimental effort uses LANL’s world leading UltraCold Neutron facility to produce neutron that move slower that a human can run. These neutrons are then held in bottles until they decay and the resulting particles are studied to gain a deeper understanding of the physical laws that govern the decay process.

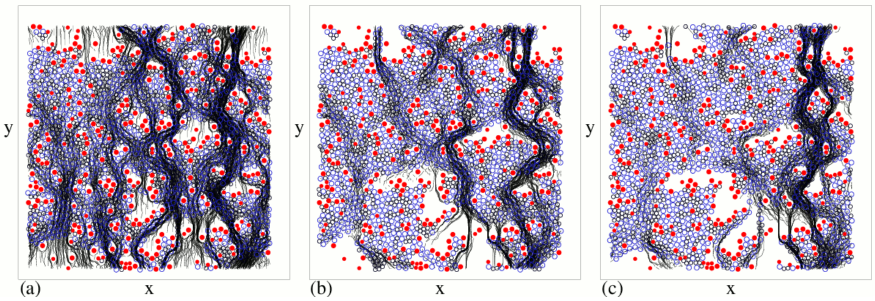


The use of UCN allows the full containment of the neutrons inside a calorimeter that measures the decay energy.

Jamming and Clogging in Artificial Ion Channels (Poster 34)

Cynthia Reichhardt (PI), L. Lopatina, I. Martin, C. Reichhardt, D. Svyatskiy

Artificial nanochannels can be used to create highly sensitive single molecule detectors that are capable of detecting small quantities of biomolecules or infectious agents. We have developed a hybrid simulation tool for studying complex charge interactions among ions moving through the channel. These interactions result in coupling, jamming, complex flows, and changes in flows. The effects on conductivity and memory could be exploited on lab-on-a-chip applications.



Clogging of ion flow due to interactions with fixed charges in the outer ion channel membrane leads to memory effects based on the complex flow pattern that develops.

Notes

Laboratory Directed Research and Development
Los Alamos National Laboratory
505-667-1235 (phone)
ldrd@lanl.gov (email)
http://tri-lab.lanl.gov/